

May 16, 2000

MEMORANDUM TO: SFPO Staff Members

FROM: E. William Brach, Director
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

SUBJECT: ISSUANCE OF REVISION 1 OF SFPO DIRECTOR'S INTERIM
STAFF GUIDANCE DOCUMENT 11

Attached for your use and information is Revision 1 of the Spent Fuel Project Office (SFPO) Director's Interim Staff Guidance Document 11 (ISG-11). This revised interim staff guidance concerns the issue of "Transportation and Storage of Spent Fuel Having Burnups in Excess of 45 GWd/MTU."

This document is being provided to ensure consistent reviews by the SFPO staff. If you have any comments or questions about the attached guidance document, please contact your immediate supervisor.

Attachment: As stated

CONTACT: Kim Gruss, SFPO/NMSS
301-415-8586

Earl P. Easton, SFPO/NMSS
301-415-8520

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Spent Fuel Project Office
Interim Staff Guidance - 11, Revision 1

Issue: Transportation and Storage of Spent Fuel Having Burnups in Excess of 45 GWd/MTU

The Standard Review Plans (SRPs) for transportation and storage of spent nuclear fuel (i.e., NUREG-1536, NUREG-1617, and NUREG-1567) do not address fuel having burnups in excess of 45 GWd/MTU. For spent fuel having average assembly burnups less than 45 GWd/MTU, there is sufficient experimental data to support the long-term and short-term temperature limits that are specified in the SRPs. Thus, the staff has reasonable assurance that spent fuels with average assembly burnups up to 45 GWd/MTU can be transported and stored safely.

The staff has recently evaluated the technical basis for the transportation and storage of spent fuel assemblies with average assembly burnups exceeding 45 GWd/MTU. This Interim Staff Guidance (ISG) addresses the technical review aspects associated with cladding integrity and specifies the acceptance criteria for the transportation and storage of these higher burnup fuels.

Regulatory Basis

In accordance with 10 CFR Part 71, the geometric form of the contents in a spent fuel package should not become substantially altered under the conditions specified for normal and hypothetical accident conditions of transport as analyzed and specified in the Safety Analysis Report (SAR). Under normal conditions of transport, the licensee must assure there would be no loss or dispersal of spent fuel, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the spent fuel package as required by 10 CFR 71.43(f). Similarly, under hypothetical accident conditions, the licensee must assure that any cladding damage would not result in exceeding the criticality requirements of 10 CFR 71.55(e) and the shielding and containment requirements of 10 CFR 71.51.

In accordance with 10 CFR 72.122 (h)(1), the spent fuel cladding must be protected during storage from degradation that leads to gross ruptures, or the fuel must otherwise be confined so that degradation of the cladding will not impose operational safety problems. Furthermore, 10 CFR 72.122(l) requires that the storage system be designed to allow ready retrieval of the spent fuel from the storage system.

Technical Review Guidance

The staff, with assistance from Pacific Northwest National Laboratory (PNNL), has recently evaluated the potential impact of storage conditions on the cladding integrity of fuels with average assembly burnups exceeding 45 GWD/MTU [Ref. 3].

The staff believes that Zircaloy cladding can withstand uniform creep strains (i.e., creep prior to tertiary or accelerating creep strain rates) of about 1% before the cladding can become perforated if the average hydrogen concentration in the cladding is less than about 400 to 500 parts per million (ppm). This amount of hydrogen corresponds to an oxide thickness of approximately 70-80 micrometers using the recommended hydrogen pickup fraction of 0.15 from Lanning, et al., [Ref. 4] and Garde [Ref. 2]. The staff also believes that the strength and

ductility of irradiated Zircaloy do not appear to be significantly affected by corrosion-induced hydrides at hydrogen concentration levels up to approximately 400 ppm. Additionally, one of the creep mechanisms of the Commercial Spent Fuel Management (CSFM) methodology for calculating cladding temperature limits [Ref. 1 and Ref. 5] namely, grain boundary sliding, provides a theoretical basis to expect cladding to accommodate uniform creep strains of about 1% without perforation for cladding with hydrogen levels in the 400-500 ppm range. Therefore, the staff has reasonable assurance that fuels having average assembly burnups exceeding 45 GWd/MTU can be safely stored and transported if the following acceptance criteria are met:

- I. A high burnup fuel assembly (i.e., burnups greater than 45 GWd/MTU) containing Zircaloy clad fuel may be treated as intact if both of the following conditions are met:
 - A1. No more than 1% of the rods in the assembly have peak cladding oxide thicknesses greater than 80 micrometers.
 - A2. No more than 3% of the rods in the assembly have peak cladding oxide thicknesses greater than 70 micrometers.
- II. A high burnup fuel assembly should be treated as potentially failed fuel if either of the following conditions are met:
 - B1. The fuel assembly does not meet both criteria A1 and A2; or
 - B2. The fuel assembly contains fuel rods with oxide that has become detached or spalled from the cladding.

The administrative controls section of the SAR technical specifications should specify a program to be implemented by the cask licensee to assure the criteria described above are met prior to loading the cask with high burnup fuel. As part of this program, the licensee may use cladding oxidation thickness measurements or predictions based on consideration of reactor operation variables affecting peak cladding oxidation; i.e., in-core flux, length of a cycle, number of cycles, power excursions, coolant temperature and amount of time at that temperature, the coolant water chemistry, and the cladding material. In cases where there are no previously documented measurements of the oxide thickness to validate cladding oxidation predictions, the program may have to incorporate peak cladding oxide thickness measurements.

For the transportation or storage of fuel assemblies meeting criteria A1 and A2, the applicant should assume, in the containment or confinement analysis of the SAR, that the source term of 50% of the rods with peak cladding oxide thicknesses greater than 70 micrometers are available for release from the cask unless justification for a different fraction is presented. This source term should be added to the source term from the assumed rod breakage fraction identified in the appropriate SRP for normal and off-normal conditions as appropriate for transportation or storage. For the criticality, thermal, and shielding analyses, the applicant should demonstrate that 10 CFR Part 71 and 10 CFR Part 72 requirements are met assuming that the rods with oxide thickness greater than 80 micrometers in a high burnup fuel assembly are failed (e.g., the fuel is allowed to redistribute in a cask) under normal, off-normal, and accident conditions.

For the transportation of individual rods, the applicant should assume, in the containment analysis, that the source term of 50% of the rods with peak cladding oxide thicknesses greater than 70 micrometers is available for release from the cask unless justification for a different fraction is presented. This source term should be added to the source term from the assumed rod breakage fraction identified in the appropriate SRP for normal and off-normal conditions, as appropriate for transportation. For rods with peak cladding oxide thickness greater than 70 micrometers, the cask design should provide a means to assure the fuel geometry during normal and hypothetical accident conditions.

For fuel with average assembly burnups greater than 45 GWd/MTU meeting criteria A1 and A2, the applicant should employ an acceptable methodology (e.g., CSFM methodology) for calculating cladding temperature limits using a 1% creep strain limit. Further, the analysis should demonstrate that the reduced cladding thickness due to oxidation does not compromise the structural ability of the cladding to withstand the expected loads encountered during transportation and storage under normal, off-normal, and accident conditions.

Fuel assemblies that meet criteria B1 or B2 should be handled in accordance with ISG-1, "Damaged Fuel." Alternatively, these fuel assemblies may be treated as intact fuel provided the appropriate demonstration of cladding integrity for these assemblies under normal, off-normal, and hypothetical accident conditions of transportation and storage is included in the SAR. Acceptable data and analyses to support the demonstration of cladding integrity may include, but are not limited to, the following:

- An estimation of the peak cladding oxide thickness and amount of hydrogen absorbed by the cladding during reactor operation to ensure that the oxide thickness and hydrogen concentration associated with hydride embrittled zirconium alloys are below those that could significantly reduce the ductility or overall integrity of the cladding.
- A calculation of the cladding hoop stress to establish both the parameters of the accelerated creep tests and the accuracy of the cladding life prediction. The stress calculation should account for the effects of (1) a reduction of thickness due to cladding oxidation, and (2) the fuel rod internal pressure considering the initial fill gas, the release of fission gases to the rod free volume, the generation of any other gases (e.g., helium, etc.) due to effects caused by the irradiation of any internal cladding coatings and the gas temperature.
- Experimentally derived data and analyses to identify the cladding failure mechanism(s) under expected transportation or storage conditions.

Recommendation

The staff proposes that NUREG-1536, NUREG-1617, and NUREG-1567 be modified to permit the transportation and storage of high burnup fuel assemblies if the cladding integrity acceptance criteria, as described above, are met. This ISG will result in modifications to the thermal, containment, criticality, and shielding chapters of these SRPs.

Approved: /RA/	Original signed by /s/	May 16, 2000
E. William Brach, Director	Date	
Spent Fuel Project Office		

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1. Cunningham, M.E., et al., Pacific Northwest National Laboratory, "Control of Degradation of Spent LWR Fuel During Dry Storage in an Inert Atmosphere," PNNL-6364, 1987.
2. Garde, A.M., "Hot Cell Examination of Extended Burnup Fuel From Fort Calhoun," DOE/ET/34030-11, September 1986.
3. Gilbert, E.R., C.E. Beyer, and E.P. Simonen, Pacific Northwest National Laboratory, "Technical Evaluation Report of WCAP-15168 (Dry Storage of High Burnup Spent Fuel)," February 2000.
4. Lanning, D.D., et al., Pacific Northwest National Laboratory, "FRAPCON-3: Modifications to Fuel Rod Material Properties and Performance Models for High Burnup Applications," NUREG/CR-6534, Vol. 1 (PNNL-11513, Vol. 1), 1997.
5. Levy, I.S., et al., Pacific Northwest National Laboratory, "Recommended Temperature Limit for Dry Storage of Spent Light Water Reactor Zircaloy-Clad Fuel Rods in Inert Gas," PNNL-6189, 1987.